

# BOOTES Observation of GRB 080603B

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## ABSTRACT

We report on multicolor photometry of long GRB 080603B afterglow from BOOTES-1B and BOOTES-2. The optical afterglow has already been reported to present a break in the optical lightcurve at  $0.12 \pm 0.2$  days after the trigger. We construct the lightcurve and the spectral energy distribution and discuss the nature of the afterglow.

**Key words.** gamma-ray bursts, individual, GRB 080603B

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## 1. Introduction

GRB 080603B was a long gamma-ray burst detected on June 3, 2008, at 19:38:13 UT by *Swift*-BAT (Mangano et al., 2008b). The burst was also detected by *Konus-WIND* (Golenetskii et al., 2008) and *INTEGRAL-SPI/ACS* (Rau, 2012).

In X-rays, the afterglow was detected by *Swift*-XRT, providing a rapid and precise localization (Mangano et al., 2008a).

The optical afterglow was observed by several telescopes - ROTSE III (Rujopakarn et al., 2008), TAROT (Klotz et al. (2008a), Klotz et al. (2008b), Klotz et al. (2009)), TLS Tautenburg (Kann et al., 2008), RTT150 (Zhuchkov et al., 2008), the Liverpool Telescope (Melandri et al., 2008), Xinglong EST (Xin et al., 2008), the 1.0m telescope at CrAO (Rumyantsev and Pozanenko, 2008; Rumyantsev et al., 2008), the 1.5 m telescope of Sayan observatory (Klunko and Pozanenko, 2008) and from Maidanak (Ibrahimov et al., 2008). In infrared by PAIRITEL (Miller et al., 2008), spectroscopy was obtained by the NOT (Fynbo et al., 2008) and the Hobby-Eberly Telescope (Cucchiara and Fox, 2008), providing a redshift of  $z=2.69$ .

An upper limit on radio emission was set by the VLA (Chandra and Frail, 2008).

## 2. Observations

At both BOOTES stations, the GRB happened during twilight, delaying follow-up by  $\sim 1$ h. Despite the delay, the optical afterglow is well detected in the data from both telescopes.

The 60 cm telescope BOOTES-2/TELMA, in La Mayora, Málaga, Spain, started taking data at 20:29:19 UT, i.e. 51 minutes after the GRB trigger. A sequence of  $r'$ -band exposures was

taken, and later, after confirming the detection of the optical transient,  $i'$ ,  $g'$  and Y band images were obtained. In the near infrared Y band, despite 600 s of integration, the afterglow was not detected.

The 30 cm telescope BOOTES-1B, located in El Arenosillo, Huelva, Spain, (Jelínek et al., 2010) obtained 368 unfiltered images totalling more than 6 hours of integrated light until the end of the night. The images were combined to improve signal-to-noise, to yield 11 data points for the period between 1.2 and 5.2 hours after the GRB. One point has a large error due to clouds crossing the field of view.

Best fit astrometric position of the afterglow, obtained from the weighted average of all available images from BOOTES-2 is

$$\alpha = 11 : 46 : 07.73 \quad \delta = +68 : 03 : 39.9 \quad (J2000),$$

about  $1.6^\circ$  SE from star  $\lambda$  Dra.

Photometry was done in the optimal aperture using IRAF/Daophot. Calibration was performed against three SDSS (DR8)(Eisenstein et al., 2011) stars. The stars are marked on the identification chart (Fig. 2) and their brightnesses are in the Table 1. Our unfiltered, "Clear", best fit magnitude  $\text{Clear} = A_1 * g' + A_2 * r'$  used for BOOTES-1B calibration is mentioned as well.

For the summary of our observations, see Table 2.

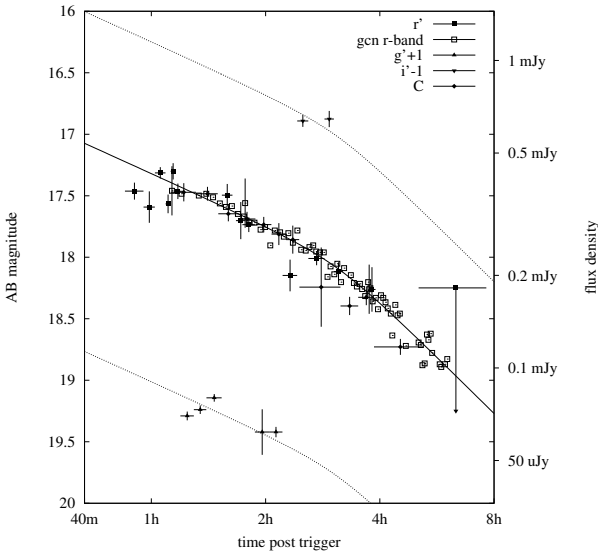
**Table 1.** Calibration stars used.

ID.	$g'$	$r'$	$i'$	Clear
1	18.00	17.50	17.32	17.52
2	18.80	17.35	16.04	17.35
3	19.88	18.42	17.09	18.47

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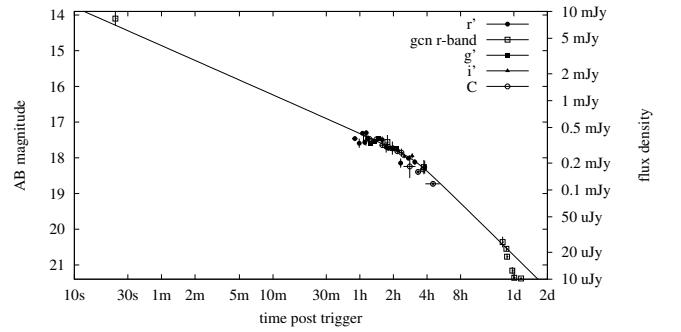
**Table 2.** Optical photometric observations of the optical afterglow of the GRB 080603B.

UT Date of mid exp.	$T - T_0[h]$	tel.	filter	$T_{\text{exp}}[s]$	mag	$\delta$ mag
Jun 3.855805	0.902	B-2	r'	3×120 s	17.46	0.07
Jun 3.859348	0.987	B-2	r'	2×120 s	17.59	0.13
Jun 3.862188	1.056	B-2	r'	2×120 s	17.31	0.05
Jun 3.864311	1.107	B-2	r'	120 s	17.57	0.08
Jun 3.865747	1.141	B-2	r'	120 s	17.30	0.07
Jun 3.867151	1.175	B-2	r'	120 s	17.46	0.06
Jun 3.868946	1.218	B-1B	Clear	10×60 s	17.53	0.07
Jun 3.870011	1.243	B-2	g'	3×120 s	18.29	0.04
Jun 3.874248	1.345	B-2	g'	3×120 s	18.24	0.04
Jun 3.876758	1.405	B-1B	Clear	10×60 s	17.54	0.06
Jun 3.879225	1.465	B-2	g'	4×120 s	18.14	0.03
Jun 3.884248	1.585	B-2	r'	3×120 s	17.50	0.09
Jun 3.884664	1.595	B-1B	Clear	10×60 s	17.70	0.06
Jun 3.889912	1.721	B-2	r'	3×120 s	17.70	0.15
Jun 3.892654	1.787	B-1B	Clear	10×60 s	17.75	0.06
Jun 3.893455	1.806	B-2	r'	4×120 s	17.74	0.06
Jun 3.899839	1.959	B-2	g'	5×120 s	18.42	0.19
Jun 3.900620	1.978	B-1B	Clear	10×60 s	17.79	0.06
Jun 3.906961	2.130	B-2	g'	5×120 s	18.42	0.04
Jun 3.908509	2.167	B-1B	Clear	10×60 s	17.87	0.09
Jun 3.914867	2.320	B-2	r'	4×120 s	18.15	0.13
Jun 3.916482	2.359	B-1B	Clear	10×60 s	17.91	0.11
Jun 3.922694	2.508	B-2	i'	5×120 s	17.89	0.05
Jun 3.931774	2.726	B-2	r'	7×120 s	18.01	0.06
Jun 3.934988	2.803	B-1B	Clear	35×60 s	18.30	0.32
Jun 3.940845	2.943	B-2	i'	5×120 s	17.88	0.07
Jun 3.947882	3.112	B-2	r'	5×120 s	18.12	0.08
Jun 3.956941	3.330	B-1B	Clear	20×60 s	18.45	0.07
Jun 3.971736	3.685	B-1B	Clear	21×60 s	18.38	0.06
Jun 3.977109	3.814	B-2	r'	5×120 s	18.26	0.18
Jun 4.006997	4.531	B-1B	Clear	78×60 s	18.79	0.07

**Fig. 1.** The detail of the optical light curve of GRB 080603B showing the observations by BOOTES (filled symbols) and from literature (empty symbols).

### 3. Fitting The Lightcurve

The lightcurve, as already shown by Zhuchkov et al. (2008) shows a smooth transition between two decay slopes  $\alpha_1 =$

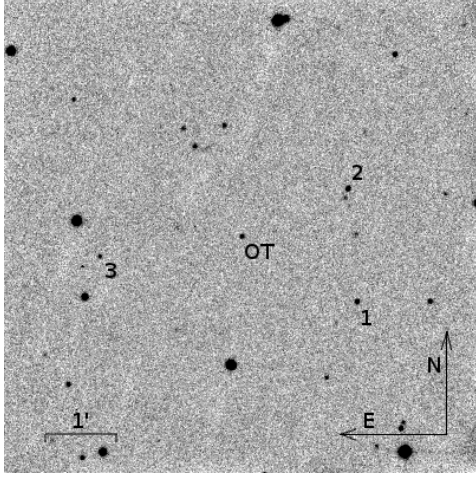
**Fig. 2.** The overall view of the light curve of GRB 080603B.

$-0.55 \pm 0.16$  and  $\alpha_2 = -1.23 \pm 0.22$ . The break occurs at  $t_b = 0.129 \pm 0.016$  days.

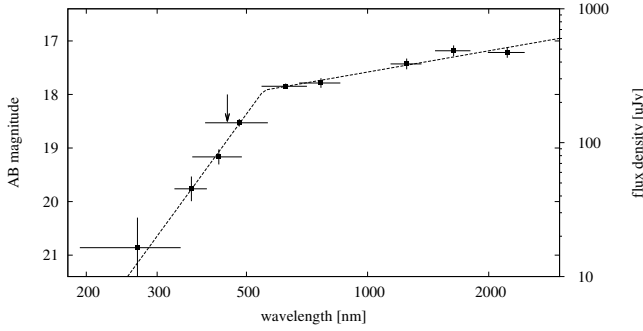
There is no hint of chromatic evolution within the lightcurve so all filters were scaled and fitted together with the  $r'$ -band. The fitting of the lightcurve was performed in  $\log t / \log f$  space, where power law functions, typical for gamma-ray bursts, show as straight lines. We used a hyperbolic transition between two slopes (smoothly broken power-law):

$$h(a, b) = a + \frac{b}{2} \sqrt{1 + \frac{a^2}{b^2}}$$

$$m(t) = m_0 - 2.5\alpha_2 \log \frac{t}{t_b} + h(-2.5(\alpha_1 - \alpha_2) \log \frac{t}{t_b}, G)$$



**Fig. 3.** The finding chart of the afterglow of GRB080603B. Combination of images taken by BOOTES-2.



**Fig. 4.** The spectral energy distribution of the afterglow in rest frame. The small arrow marks Ly- $\alpha$  position for  $z = 2.69$ .

Where  $\alpha_1$  and  $\alpha_2$  are pre-break and post-break decay indices,  $t_b$  is the break time,  $m_0$  is an absolute scaling parameter of the brightness and  $G$  expresses smoothness of the break.

Although the early point by ROTSE (Rujopakarn et al., 2008) was not used, it agrees with the backward extrapolation of the  $\alpha_1$  slope and so supports this simple interpretation.

We constructed a spectral energy distribution (SED) by fitting the needed magnitude shift of the R-band lightcurve model to the photometric points from BOOTES, UVOT (Mangano et al., 2008b) and PAIRITEL (Miller et al., 2008) obtained in other filters. While the points from UVOT are practically contemporaneous to BOOTES, PAIRITEL observed rather later (0.32 days after trigger), so the SED is therefore model-dependent in its infrared part. The synthetic AB magnitudes equivalent to  $t = 0.1$  days are in Table 3.

The SED shows a clear suppression of radiation above  $4500\text{\AA}$ , i.e. redshifted Ly- $\alpha$  line. No radiation is detected above the Lyman break at  $3365\text{\AA}$ . A rather shallow power law with an index  $\beta = -0.53 \pm 0.06$  was found redwards from  $r'$  band. The fit was performed using the  $E(B-V) = 0.013$  mag (Schlegel et al., 1998).

The strong suppression of light for wavelengths shorter than  $r'$  band is likely due to the Ly- $\alpha$  absorption within the host galaxy and Ly-alpha line blanketing for  $z=2.69$ .

**Table 3.** The spectral energy distribution in AB magnitudes equivalent to 0.1 days after the trigger. ( $^\dagger$  UVOT,  $^\ddagger$  PAIRITEL)

Filter	$m_{AB}$	$\Delta m_{AB}$
$W^\dagger$	20.98	0.56
$U^\dagger$	19.83	0.23
$B^\dagger$	19.22	0.14
$g'$	18.57	0.07
$r'$	17.88	0.05
$i'$	17.81	0.09
$J^\ddagger$	17.44	0.10
$H^\ddagger$	17.19	0.10
$K^\ddagger$	17.22	0.10

#### 4. Discussion

The values of  $\alpha_2 = -1.23 \pm 0.22$  and  $\beta = -0.53 \pm 0.06$  both point to a common electron distribution parameter  $p = 2.05 \pm 0.20$  ( $\alpha = (3 * p - 1)/4$ ,  $\beta = (p - 1)/2$ ) (Piran, 2004). Such a combination suggests a stellar wind profile expansion and a slow cooling regime.

The pre-break decay rate  $\alpha_1 = -0.55 \pm 0.16$  remains unexplained by the standard fireball model. It is unlikely that the break at  $t_b = 0.129 \pm 0.016$  would be a jet break. It is quite possible that the plateau is not really a straight power law, and that some late activity of the inner engine may be producing bumping of hydrodynamic origin.

We note that the literature contains a number of observations suggesting a rapid decay by about one day after the GRB. Without having all the images, it is, however, impossible to decide whether this is a real physical effect or a zero-point mismatch.

#### 5. Conclusions

The 0.6 m telescope BOOTES-2 in La Mayora observed the optical afterglow of GRB 080603B in three filters. The 0.3 m BOOTES-1B in El Arenosillo observed the same optical afterglow without filter.

Using the data we obtained at BOOTES and from the literature, we construct the lightcurve and broadband spectral energy distribution.

Our fit of the obtained data provides the decay parameters  $\alpha_2 = 1.23 \pm 0.22$  and  $\beta = -0.53 \pm 0.06$ , which suggest a slow cooling expansion into a stellar wind.

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